STEM RUST IN 1935

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Factors Affecting the Development of the Epidemic

The question naturally arises as to why the stem rust epidemic in 1935 was so severe after the barberry eradication program has been going on for a number of years and after considerable work has been done in attempting to develop rust-resistant varieties of wheat.

First of all, barberry eradication will not entirely eliminate stem rust. It has been known for many years, and the fact has repeatedly been emphasized in publications, that the red or summer stage of stem rust overwinters nearly every year in southern Texas and occasionally in northern Texas. However, stem rust can not survive the winter in the stage that is capable of attacking grains and grasses in Minnesota and the Dakotas. It survives here in the black or winter stage, which can attack only barberries, from which the rust then spreads to grains and grasses. Consequently, if all of the barberries are removed from the Northern States, there will be no local source of rust. There are, then, two possible sources of rust in the North: (1) That which comes directly from the barberries within these States; (2) that which may be blown in from Texas or surrounding States.

With a large number of barberries in grain-growing regions, rust develops every year that weather conditions are favorable. Even if weather is only moderately favorable, considerable damage may be done be cause the rust gets started early in the spring -- as early as the first week in May -- and then has a long time before harvest in which to multiply and develop. The object of barberry eradication is to eliminate this early source of rust and to eliminate the thousands of small rust outbreaks of the early spring which, in favorable seasons, unite to form regional or even general epidemics. The eradication of approximately 20 million barberry bushes from the Northern States to date has undoubtedly resulted in saving millions of dollars to grain farmers during the past 15 years. Even this year there is a very strong likelihood that rye and oats would have suffered considerable loss had the

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barberry eradication program not progressed as far as it has. It is very probable, also, that barley would have been injured far more than it was. As it is, only wheat was severely damaged. The reason for this is that the stem rust on wheat will not infect oats, nor rye; while that on oats and rye will not infect wheat. There was little stem rust of oats in the South to be blown northward. Thus, barberry eradication not only has resulted in very decided savings to grain growers in the past 15 years but it has protected oats and rye and, to a certain extent, barley this year. What would have happened had barberry eradication not been carried on was indicated this year by the development of local epidemics on rye near barberries. It appears evident that, if the barberries had not been pushed back into the woods and into brush land, that is, had there still been millions of the bushes near grain fields, there would have been an epidemic on oats this season, and, to a lesser extent, an epidemic on rye.

Conditions that made possible the destructive epidemic on wheat may be summarized as follows. Stem rust overwintered in the summer stage on winter wheat to an unusual extent in Texas. Furthermore, there were large areas of wheat in Kansas and Nebraska in which the plants were killed to the ground by drought early this spring. Later there were heavy rains, and the wheat grew again from the roots. This wheat was still green for several days after the usual harvest date. It became very heavily rusted and therefore constituted a menace to the wheat in States farther north. Beginning about June 20 there were strong south winds, culminating in a very heavy wind on June 24. On this date tremendous numbers of rust spores were blown into the Northern States.

Rains and heavy dews followed, providing ideal conditions for the infection of wheat with this rust. Until almost harvest time the weather continued ideal for rust development, viz.: high temperatures and, for a considerable period of the time, high humidity. The rust developed with amazing rapidity, resulting in the epidemic. It must be remembered, also, that the wheat was a week or ten days later than normal, thus permitting a longer period for rust development. Stands were heavy -- a condition further favoring spread of the disease. From the time the wheat headed until it ripened prematurely because of the intense heat, the conditions were almost ideal for the development of rust, and the result was extremely heavy losses approaching complete ruin in some areas.

It should be emphasized, therefore, that stem rust epidemics may occasionally occur even in the absence of barberries. However, in order for an epidemic to develop in the Northern States after the remaining barberry bushes have been destroyed would require certain conditions which may be summarized as follows: (1) Rust would have to be blown into Texas in considerable quantity from the Northern States in the fall, because it is killed out by the hot dry summers in the South; (2) conditions would have to be favorable for the widespread infection of winter wheat soon after the rust was blown into Texas; (3) conditions would need to be favorable throughout the winter for the overwintering of the summer stage in Texas; (4) weather conditions would have to be favorable for the

rapid multiplication of rust in Texas in the spring; (5) strong south winds would have to carry the rust into the Northern States before July 1 in the average year; (6) weather conditions would have to be favorable for the development of rust in the Northern States after it arrived from the South. Obviously a season in which all of these events followed each other in this sequence would be rare. On the other hand, with large numbers of barberries in the Northern States, there would be a local source of rust early in the spring in virtually every township in the grain-growing districts of these States, and it would be far easier for epidemics to develop, and they undoubtedly would develop far more frequently. Barberry eradication, therefore, while not eliminating the possibility of epidemics, renders their development very much less likely.

Physiologic Forms of Stem Rust on Barberry

Another very important reason for eradicating barberries which is not generally understood is the fact that new parasitic strains of the rust are produced on the bushes. There are several different varieties of the rust fungus, as follows: the tritici or wheat variety, the avenae or oats variety, the secalis or rye variety, the phleipratensis or timothy variety, the agrostidis or red top variety, and the poae or blue grass variety.

The phleipratensis or timothy variety attacks timothy, and attacks oats, rye, and barley to a slight extent, but does not attack wheat. The agrostidis or red top variety attacks red top and a number of the other grasses but it is not able to attack any of the small grains heavily enough to be of any importance. The poae or blue grass variety attacks blue grass and closely related species of grasses but does not attack any of the small grains sufficiently to be of any importance on the grains.

The tritici variety attacks wheat and barley but not oats and rye. The secalis variety attacks rye and barley but not wheat and oats. The avenae variety attacks oats but not wheat, barley, and rye. It is evident, therefore, that the rust can pass freely from wheat to barley and from rye to barley. But it passes from barley and rye only if it happens to be the secalis variety on barley, and it passes to wheat from barley only if the rust on the barley happens to be of the tritici variety. The rust can not pass from any of the other common small grains to oats, nor from oats to any of the other small grains. These rust varieties also can attack certain wild grasses.

All of these varieties of rust can attack the common barberry and are enabled to persist by means of it, as the rust can pass first to wild grasses and then to grains.

The three varieties of stem rust that attack the small grains in turn comprise parasitic strains which can be distinguished from each other by their effect on certain varieties of wheat, rye, and oats, respectively. For example, the tritici or wheat variety of stem rust comprises approximately 150 distinct parasitic strains. Some of these

attack certain bread wheats but not others; some attack the bread wheats but not the durums. Still other strains attack certain durum varieties and certain bread wheat varieties but not other varieties of bread wheat. It has been shown that these parasitic strains originate by hybridization between existing parasitic strains on the common barberry. 1/,2/ Thus the barberry is the breeding place for new parasitic strains, and it has been shown definitely that these parasitic strains complicate the problem of breeding rust-resistant varieties of grain. For example, Kanred wheat is immune from a number of parasitic strains but completely susceptible to others. Therefore, Kanred may be free from rust in those regions and seasons where and when there are parasitic strains that do not attack it. In other regions or seasons, however, Kanred may be virtually ruined by rust because of the presence of parasitic strains to which it is susceptible. The same thing is true of the durum wheats. They may rust in those regions and in those seasons where and when parasitic strains are prevalent that attack them normally. Because of the existence of so many parasitic strains and the continual production of new ones on the common barberry, it has been necessary to attempt to breed varieties of wheat which are resistant to all of the parasitic strains because of the toughness of the stem or other structural characters. It is known, however, that the resistance of such varieties varies considerably, depending on the conditions under which the plants are grown. While gratifying progress has been made in the breeding of resistant varieties, the very nature of the situation makes it possible, and even probable, that varieties may be resistant for a certain length of time and then suddenly prove susceptible, or they may be resistant in certain regions and seasons but not in others.

Rust resistance, like most other plant characters, varies greatly with the conditions under which the plants are grown. Breeding, therefore, must be a continuous process. Resistant varieties may be resistant for a time and hence extremely useful, but the rust situation is continually changing because of perfectly natural changes and plant breeders must look forward to the prospect of producing new varieties from time to time to meet the new conditions. One of the greatest obstacles to a final solution of the rust problem through breeding of resistant varieties is the fact that new parasitic strains are continually being produced. These strains are produced on the barberry, and their existence makes it necessary to attempt to breed varieties which are resistant to, or can withstand the attack of, all of these parasitic strains because of certain structural or behavioristic characters. Through the eradication of barberry the number of parasitic strains will be reduced, because some of those already in existence will die out in unfavorable seasons and new ones can not be produced in the absence of barberries (unless very occasionally through mutation). When the number of rust strains has been reduced, it will be possible to use a wider range of varieties in breeding work, because breeders will not be restricted to the use of parental

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1/ Stakman, E. C., M. N. Levine, Ralph U. Cotter, and Lee Hines. Relation of barberry to the origin and persistence of physiologic forms of Puccinia graminis. Jour. Agr. Res. 48: 953-969. 1934

2/ Levine, M. N., R. U. Cotter, and E. C. Stakman. The production of an apparently new variety of Puccinia graminis by hybridization on barberry (Abs.). Phytopath. 24: 13-14. 1934

material with one general type of resistance. It is significant that European countries are beginning to realize this and are intensifying their efforts to eradicate the common barberry, not only because they produce a great deal of rust in the spring but also because they make the problem of developing resistant varieties far more difficult. Most significant of all, perhaps, is the fact that under date of July 9, 1935, the Governor of the State of New South Wales in Australia, on advice of the executive council, issued a proclamation requiring the destruction of all barberries. In this case the objective is to prevent the production of new parasitic strains.

These conclusions are substantiated by experience this year. So far in 1935 (August 15) there have been isolated from barberries 18 forms in 82 collections, while from wheat away from barberries there have been isolated 14 forms from 340 collections. A different physiologic form has been obtained, therefore, in about every five collections of rust from barberry, whereas in wheat a different form has been obtained in only about every 24 collections. The most significant fact, however, is that from barberries there have been isolated parasitic strains that attack varieties of wheat or emmer that are normally highly resistant to the parasitic strains that are usually found away from barberry. For example, not a single form that attacks Vernal emmer has been isolated from wheat, whereas from barberries three have been isolated, viz., Forms 15, 57, and 121. The most virulent form known at present which attacks bread wheats, durums, and emmers is Form 15. Inasmuch as the resistant parent of Hope wheat, which is widely used as a resistant parent in crosses, is an emmer, the significance of the presence of such parasitic strains as No. 15 on barberries must be seriously considered.

Rust-resistant Varieties of Wheat

Considerable disappointment has been expressed because supposedly resistant varieties of wheat have been severely injured this year. This has been particularly true of Ceres, which in many regions was injured as severely as the non-resistant Marquis and which was rusted far more heavily in all regions than most people suspected it could be. It has been known since Ceres was introduced that, altho resistant, it was not immune from rust. This year, when the crop was grown, for the most part, in a very moist soil and under cool, cloudy conditions until late in June, the plants were more tender than they normally would be, the stands were dense, the crop late, and the result was that, with the large number of spores in the air, Ceres rusted heavily.

Minturki, a hard red winter wheat, which usually either is highly resistant to rust or escapes it, also rusted very heavily in some localities. The experience with Ceres and Minturki this year, as well as with Kota and Marquillo during other seasons, indicates that even very highly resistant varieties may under certain climatic conditions rust heavily if they are subjected to heavy inoculation with rust. Were the barberries permitted to remain, it is certain that resistant varieties so far developed and distributed might become heavily rusted if the bar-

berry bushes were discharging billions of spores in the immediate vicinity of the fields. The eradication of barberries gives these resistant varieties a chance to develop without great damage from rust or from new strains of the rust.

It should be realized also that rust resistance in varieties so far known is a variable character like any other plant character. Recent investigations have shown that even so resistant a variety as Hope may rust quite normally when light intensity is reduced. Under cloudy conditions, therefore, when there is considerable moisture and large numbers of rust spores in the air, even this variety may become heavily rusted. The fact that varieties like Hope and Ceres, having so-called "mature plant resistance", which has a tendency to protect them against all parasitic strains, rust heavily under certain conditions indicates clearly that, in the present state of our knowledge at least, the perfectly resistant wheat has not yet been developed for practical conditions. Even Thatcher, which appears to be by far the best resistant hard red spring wheat yet developed, was moderately rusted in certain plots in 1935. Were it to be grown under conditions unfavorable to its development and favorable to rust, there is no assurance that it might not be damaged appreciably by rust.

The problem of developing rust-resistant varieties of small grains is no easy one. The fact that there are so many parasitic strains of the stem-rust fungus and that the resistant varieties may fluctuate within wide limits makes it all the more important to eradicate barberries from the Northern States in order to help prevent highly resistant, but not immune, varieties from rusting.

The breeding of resistant varieties, like barberry eradication, should not be condemned because of the disappointment this year. Ceres wheat has saved the farmers of the Northwest millions of dollars in past seasons when the conditions for the development of rust and for the growth of the plants themselves did not combine to break down the resistance of this variety. Nevertheless, it is evident that more highly resistant varieties must be developed. The two commercial, or semi-commercial varieties that have withstood rust best this year are Marquillo and Thatcher, both developed at the Minnesota Agricultural Experiment Station in cooperation with the United States Department of Agriculture. Marquillo was injured relatively little by rust but is no longer recommended for general commercial growing because of the yellow color of the flour produced from it. Thatcher was introduced only two years ago, and not enough seed is available to plant a considerable acreage. Thatcher is the result of a so-called "double cross" which resulted from crossing Marquis with Iumillo durum, which was highly resistant to rust, and again crossing a selection from this with a selection from a Marquis x Kanred cross which has the resistance of Kanred to a considerable number of parasitic strains of wheat stem rust. It appears to be the most resistant commercial variety of hard red spring wheat so far developed and introduced.

It withstood the attacks of rust in 1935 remarkably well, and gives promise now of proving an extremely valuable variety.

No one method of rust control has so far sufficed to prevent epidemics. Combination of barberry eradication, together with further progress in the development of resistant varieties, however, will continue to reduce rust losses.